4 HUMAN USES AND RESOURCE MANAGEMENT

The Great Bay and Hampton/ Seabrook estuaries are extremely important to the local, regional, state, and national economies. From the time of first European settlement, the Great Bay Estuary has been a center of commerce for natural resource based industries such as commercial fishing and logging. During the 19th century, shoe and textile manufacturing became important and mills were built in all towns with access to navigable waterways. Today energy is produced in facilities located on the Piscataqua River and in Hampton Harbor, and the shipping of lumber, mineral salt, gypsum and other products is of significant economic importance. Several species of fish still support local and regional fisheries in the Gulf of Maine, and tourism and recreation are becoming increasingly important parts of the N.H. Seacoast economy. Many of these activities are dependent on good water quality and a healthy ecosystem. In particular, habitat degradation and declines in important fish and shellfish species remain a concern. This chapter summarizes what is known about human uses and resource management in Coastal New Hampshire to frame related issues and to assess the significance of problems and information gaps relative to the Seacoast's estuarine ecosystems.

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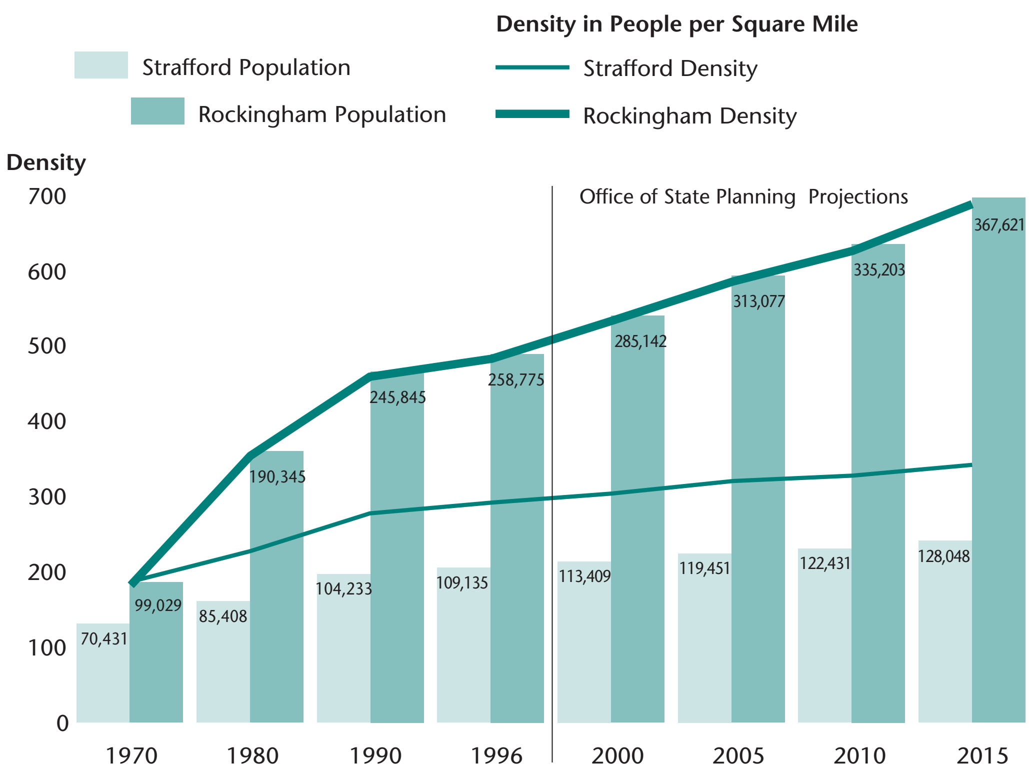
POPULATION TRENDS, EMPLOYMENT AND INCOME

4.1.1 POPULATION AND DENSITY TRENDS AND PROJECTIONS

The human population trends for Rockingham and Strafford counties from 1970 to 2015 (NHOSP, 1997a) are shown in Figure 4.1. Both Rockingham and Strafford counties had more dramatic increases in population from 1970-1990 compared to projected increases from 1990 to 2010. Rockingham County increased from 138,951 to 245,845 people from 1970 to 1990, a 77% increase while the increase was 36% in Strafford County. The populations are projected to increase from 1990 to 2010 by 48% in Rockingham County and by 18% in Strafford County. Throughout the 40 year span of data, the population of Rockingham County has been and is projected to continue to be greater than Strafford County.

Figure 4.1 shows population density trends and projected trends through 2015. The population density of Strafford County has been greater than for Rockingham County, with the difference projected to narrow as densities in both counties continue to increase through 2015. In 1990, 50.4% of the people in Rockingham County were female and 51.6% of the people in Strafford County were female (NHOSP, 1997a). The continuation of increases in population and density in New Hampshire's two coastal counties is a concern because of the accompanying increases in development, use of coastal resources and production of pollutants.

FIGURE 4.1 *Population growth in Rockingham and Strafford counties, New Hampshire: 1970-2015.*



4.1.2 EMPLOYMENT AND INCOME

The economic issues in coastal New Hampshire have been reviewed in numerous studies (Colgan, 1995; NAI, 1994; Ogrodowczyk, 1993). Much of the work focused on fisheries, but tourism, transportation, industries, and related issues were also discussed. Table 4.1, shows the harbor-related economic value and jobs generated by coastal industries (NAI, 1994). Table 4.2 shows where these activities occur in New Hampshire. The different activities take place throughout the Seacoast, but Portsmouth Harbor is the only place where all activities occur, while recreational boating is the only activity that occurs at all sites. Little Harbor anticipates an increase in recreational boating and Portsmouth Harbor anticipates an increase in commercial shipping; the rest of the harbors anticipate maintenance of similar levels of activities, which have been mostly recreational (NAI, 1994). Maintenance of current activities will require maintenance dredging, and reduced dredging would seriously impact cargo shipping, shipbuilding, cruise ship operations, and commercial fishing.

As shown in Table 4.1, commercial fishing is the industry type with the largest employment and economic activity. It encompasses the fishing, hunting, trapping, fresh or frozen prepared fish, and wholesale trade categories of economic activity. Rockingham County has the vast majority of jobs and economic activity. More information on the present status of the commercial fishing industry is provided below in the Commercial Fisheries and Aquaculture section (4.3.1.3).

The economic value and jobs generated by coastal New Hampshire industries. **TABLE 4.1**

Industry	Value in $	Jobs
commercial fishing	160 million	1065
recreational boating	18 million	55
cargo shipping	12 million	91
boatbuilding and repair	2.1 million	56
water transportation/tourism	1.7 million	14
Total	193 million	1281

TABLE 4.2

Harbor-related activities in New Hampshire.

	Cargo terminal	Tourism	Commercial fishing	Boat yards	Ferry	Recreational boating	Other
River							
Squamscott R.	—	—	x	—	—	x	
Lamprey R.	—	—	x	—	—	x	
Oyster R.	—	—	—	—	—	x	
Cocheco R.	—	x	x	x	—	x	
Harbor/Bay							
Great Bay	—	—	—	—	—	x	
Little Bay	—	—	x	x	—	x	
Portsmouth Harbor	x	x	x	x	x	x	(tugs, barges)
Portsmouth back channels	—	—	x	—	—	x	
Little Harbor	—	x	x	—	—	x	
Hampton Harbor	—	x	x	x	—	x	
Isles of Shoals	—	x	x	—	x	x	

LAND USE AND DEVELOPMENT ISSUES

4.2.1 URBAN AND RURAL DEVELOPMENT

The assessment of water quality and living resources in coastal New Hampshire benefits from addressing issues at large scales. An assessment of the land use and human activities that occur on the uplands and in the watersheds adjacent to New Hampshire's estuaries helps in the understanding of processes that affect human health issues and the integrity of the estuarine ecosystems.

Published land-use change information is limited (Coppelman et al., 1978; Befort et al., 1987; NHCRP, 1997). Data from the Complex Systems Research Center at UNH are also available. Agricultural land in New Hampshire has decreased in Rockingham and Strafford counties from 472,000 acres in 1850 to 42,000 acres in 1996, while urban lands comprised 13.9 and 8.5% of Rockingham and Strafford counties, respectively, in 1996 (NHCRP, 1997).

A critical lands analysis project conducted for the NHEP by the Complex Systems Research Center at UNH is determined the potential for development in uplands classified by land use (Rubin and Merriam, 1998). The quantity and quality of the existing information varied for each town or city in the coast. In addition, policy and program reviews of local, state and federal regulations governing land use and human activities in the region have also been conducted (Carlson et al., 2000; 1997).

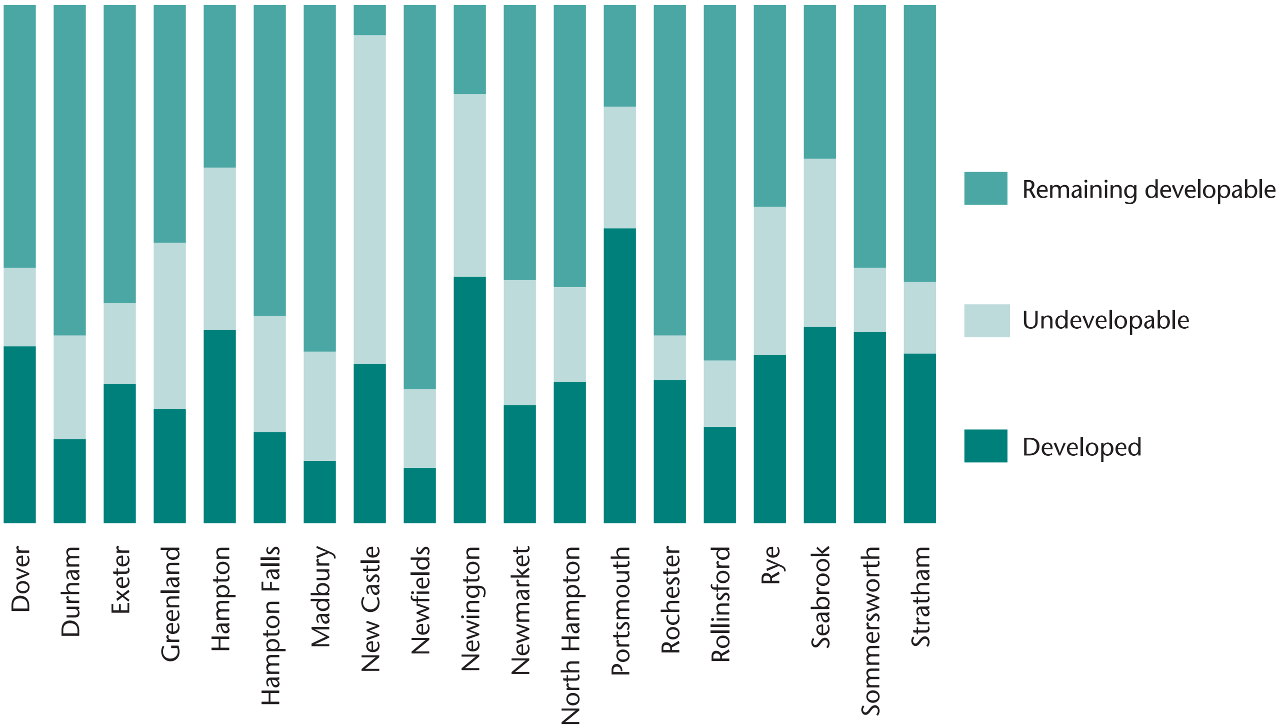
Some of the results of the critical lands analysis are summarized in Table 4.3. Data for all of the 19 coastal New Hampshire municipalities include popu-

TABLE 4.3 *Developed and undeveloped acreages in the 19 coastal New Hampshire municipalities.*

Town	Population 1992	Total area (acres)	Residential area (acres)	Ttl area developed (acres)	Remaining undevelopable (acres)	Remaining developable (acres)	Ttl developed area per capita	Ratio of remaining to ttl developable land
Dover	25114	18587	4318	6363	2826	9398	0.25	0.60
Durham	12348	15852	1865	2561	3181	10110	0.21	0.80
Exeter	12356	12813	2646	3452	1982	7379	0.28	0.68
Greenland	2790	8524	1259	1879	2719	3926	0.67	0.68
Hampton	12269	8901	2391	3319	2794	2788	0.27	0.46
Hampton Falls	1531	8078	948	1430	1797	4851	0.93	0.77
Madbury	1431	7799	649	954	1629	5217	0.67	0.85
New Castle	831	1218	301	372	773	73	0.45	0.16
Newfields	909	4647	340	491	703	3453	0.54	0.88
Newington	688	7916	578	3757	2784	1375	5.46	0.27
Newmarket	1796	9080	1715	2056	2195	4829	1.14	0.70
North Hampton	3642	8914	1913	2414	1637	4863	0.66	0.67
Portsmouth	22342	10762	2459	6123	2513	2127	0.27	0.26
Rochester	26640	29072	5252	8007	2504	18561	0.30	0.70
Rollinsford	2646	4840	178	896	619	3325	0.34	0.79
Rye	4555	8353	2205	2716	2375	3262	0.60	0.55
Seabrook	6537	5923	1407	2239	1920	1764	0.34	0.44
Sommersworth	11239	6396	1574	2351	801	3244	0.21	0.58
Stratham	5040	9902	2619	3226	1396	5280	0.64	0.62
Total	**154704**	**187578**	**35155**	**54607**	**37146**	**95825**	**0.35**	**0.64**

Notes:
"Developed" land data from regional planning commission land use maps, circa 1992.
"Remaining Undevelopable" land includes protected land, surface water, large wetlands, road and transmission rights of way, and other land types unsuitable for development.

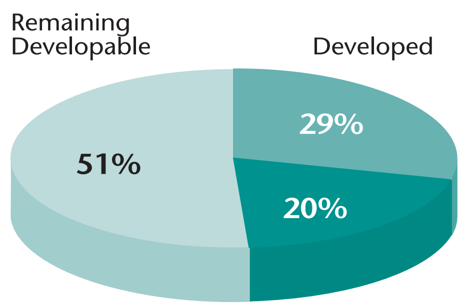
Percent land development and potential in the 19 coastal New Hampshire municipalities. **FIGURE 4.2**



lation, total acres, residential area, total developed area, and the remaining land that is either undevelopable or developable. For comparisons of different sized municipalities, a ratio of total developed area per capita is provided. Newington has the highest ratio (5.46) by far, reflecting both extensive development and a low population. Hampton Falls has the next highest (0.93) ratio, while Dover, Durham, Exeter, Hampton, Newmarket, Portsmouth, Rochester and Somersworth have low (≤ 0.3) ratios. The eight municipalities with the low ratios are also the eight with the highest populations.

Another way of comparing different municipalities is to calculate the fraction of remaining developable land compared the total area of developed and developable land (Table 4.3). A low ratio suggests that the municipality has less room to continue development. The communities with low (< 0.3) ratios are New Castle, Newington and Portsmouth. Communities with high (> 0.7) fractions are Durham, Hampton Falls, Madbury and Rollinsford. These trends are also illustrated in Figure 4.2, which also factors in undevelopable land. In the case of New Castle, the limited room to develop is a combination of having the smallest percentage of remaining developable land and the largest percentage of undevelopable land, along with a modest percentage of developed land. Portsmouth and Newington have the highest percentage (> 40%) of developed land and relatively small percentages of remaining developable land. The four communities with the smallest percentage of developed land also had the largest percentages of remaining developable land. For the whole Seacoast, 29% of the land has been developed while 51% remains developable, with 20% undevelopable (Figure 4.3).

Percent land development and potential for coastal New Hampshire. **FIGURE 4.3**



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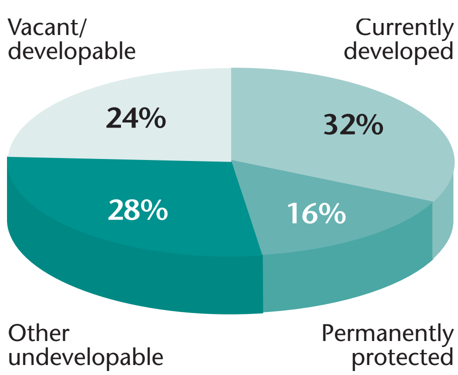
4.2.2 ESTUARINE SHORELAND

Figure 4.4 shows the percentage land use types within 300 feet of tidal waters. Comparison of Figures 4.3 and 4.4 shows that despite similar percentages of developed and undevelopable lands, there is a much lower percentage of estuarine shoreland that remains developable and much more that is undevelopable, in large part because of land that is permanently protected or extensively regulated along the state's shorelines. There is 51% of the land in all 19 coastal communities that remains developable (Figure 4.3) compared to only 24% of the land within the 300 foot shoreline buffer zone (Figure 4.4). The 16% of shoreline buffer zone lands that are permanently protected or extensively regulated constitutes 40% of the land that would otherwise be considered developable.

FIGURE 4.4

Land use types within a 300-foot shoreline buffer in New Hampshire tidal waters.



4.2.3 HABITAT LOSS AND FRAGMENTATION

Forest fragmentation is the major cause of land habitat degradation in New Hampshire (NHCRP, 1997). It is highest in Rockingham County compared to all New Hampshire counties. The average forest patch size is also smallest (39.8 A). In terms of road density, Rockingham and Strafford counties are second and third highest in the state, with 5.6 and 4.7 mi/1000 A, respectively. Not only does road density help to further fragment habitats, but roughly 10% of the total annual kills for bear and deer statewide were by roadkill. Cars killed an average of 18 bears, 153 moose and 861 deer per year from 1984-1995 (NHCRP, 1997).

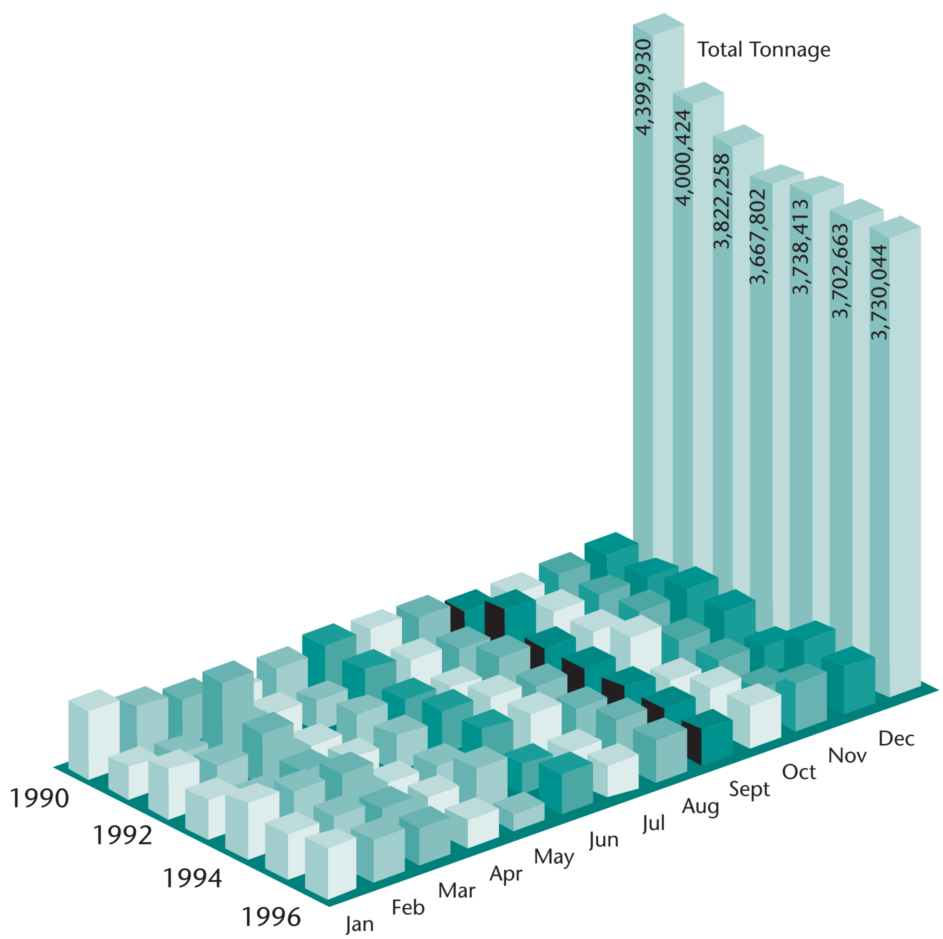
4.3.1 COMMERCIAL USES

4.3.1.1 Shipping and Commercial Vessel Traffic

Information on shipping is available through the New Hampshire Port Authority (NHPA). Monthly records of vessel arrivals and departures are recorded, along with type of vessel, home port, name, cargo, tonnage loaded and tonnage unloaded. Based on the NHPA data, the total tonnage decreased from 1990 to 1996, with a relatively consistent tonnage being shipped during all months (Figure 4.5).

NAI (1994) summarized the total shipping tonnage for New Hampshire by different categories for 1980 and 1992. The total shipping tonnage increased from 2.8 million tons in 1980 to 4.2 million tons in 1992. The largest commodity was oil, comprising approximately 2 million tons during both years. The increase from 1980 to 1992 was from increases of shipping for dry and bulk tonnage. During 1980, the dry and bulk commodities included salt, gasoline and scrap metal, with propane, asphalt and gypsum being prominent in 1992. Data from these more recent studies can be compared to earlier data. Total shipping tonnage in Portsmouth Harbor was 505,000 tons in 1949, increasing to 1.2 million tons in 1958 (NHWPC, 1960). The major commodity in 1958 was residential fuel oil (~400,000 tons), followed by gasoline, gas oil, wood manufacturing, coal and gypsum, all with greater than 100,000 tons. The new NHPA docking and storage facilities should eventually allow an

Monthly and annual shipping tonnage recorded by the New Hampshire Port Authority: 1990-1996. **FIGURE 4.5**



increase in cargo handled at the NHPA facility from 300,000 to 1 million tons (NAI, 1994).

The most widespread harbor-related activity in New Hampshire is commercial fishing. There were 428 commercial fishing vessels in New Hampshire in 1992, 264 at slips and 139 at moorings (Table 4.4; NAI, 1994). The highest number of commercial vessels were in Portsmouth (200) and Hampton (100) harbors. There were also 80 sports fishing, eight whale watching, eight windjammer/charter sail and 13 harbor tour cruise vessels in New Hampshire during 1992 (Table 4.5; NAI, 1994).

4.3.1.2 Dredge and Disposal

All known dredging in New Hampshire coastal waters since 1950 has been summarized by NAI (1994). Dredging in tidal waters is restricted to November 15-March 15 (seasonal restrictions), and does not occur during periods of fish migration or larval settlement of shellfish. NHF&G will allow exceptions to dredge schedules outside of the target dates when necessary. Most dredging has occurred to maintain and expand the commercial and recreational uses of New Hampshire's harbors (NHOF, 1979). The NAI (1994) report recommended

TABLE 4.4 *Private commercial vessels in coastal New Hampshire in 1992 (NAI, 1994).*

	Total Commercial Vessels	Commercial at Slips	Vessels at Moorings
River			
Squamscott R.	33	15	17
Lamprey R.	10	5	5
Oyster R.	3		
Cocheco R.	20	10	
Harbor/bay			
Great Bay			
Little Bay	20	16	4
Portsmouth Harbor	200	173	27
Portsmouth back channels	12		12
Little Harbor	30	20	10
Hampton Harbor	100	25	61
Total	**428**	**264**	**136**
Rockingham county	385		
Strafford county	23		
Both counties	20		

TABLE 4.5 *Tourist-related vessels in New Hampshire in 1992 (NAI, 1994).*

	Sport Fishing	Whale Watching	Windjammer/ Charter Sail	Harbor Tours/ Day Cruises
River				
Squamscott R.				
Lamprey R.				
Oyster R.				
Cocheco R.				
Harbor/bay				
Great Bay				2
Little Bay				
Portsmouth Harbor	10	3	2	5
Portsmouth back channels				
Little Harbor	30	0	4	4
Hampton Harbor	20	5	2	2
Isles of Shoals				
Total	**80**	**8**	**8**	**13**

expanded dredging in Rye, Hampton and Portsmouth harbors to enhance safety of navigation, improve recreational and commercial facilities and expand mooring spaces. It also provides a summary of historical dredging and disposal activities, regulatory programs, a valuation of harbor economic uses and a projection of future disposal needs in Maine and New Hampshire. Most of the 2.9 million cubic yards of dredging material was dredged in Rockingham County, with this material being dredged from five water bodies during 66 dredging events (Table 4.6). There were also two events in Strafford County (Little and Great bays), amounting to only ~16,000 cubic yards of material.

Dredge materials have been disposed of within intertidal, nearshore, open water, upland or unknown locations (NAI, 1994). Much of the material was dumped at the Cape Arundel, ME open water site. Some Rockingham County material was subject to chemical analysis (see Chapter 2). Most samples had low to moderate concentrations of metals, DDT and PCBs. A high PCB concentration (>2.9 ppm) was found in one sample from Hampton Harbor, and a high concentration (>125 ppm) of vanadium was found in two samples from Rye Harbor. On the Maine side of Portsmouth Harbor, high concentrations of copper (>342 ppm), lead (>285 ppm), mercury (>3.0 ppm) and zinc (>43.6 ppm) were measured in numerous samples from the Portsmouth Naval Shipyard. As in the past, much of the future dredged material in Hampton and Little harbors will be available for beach nourishment or nearshore disposal; otherwise, it will be hauled to offshore disposal sites.

4.3.1.3 Commercial Fisheries and Aquaculture

Lobsters

The commercial lobster industry in New Hampshire coastal waters, which includes Great Bay and Hampton/Seabrook estuaries, consists of 300 lobster fishers harvesting approximately $5-6 million in ex-vessel value of lobsters annually. Despite heavy fishing pressure, the lobster catch has been stable for a number of years. Commercial landings of lobsters solely from the Great Bay Estuary and Hampton Harbor were not available, but lobsters are fished commercially in all but the upper tidal reaches of the estuaries. Including all lobsters caught by the New Hampshire fishing fleet, there have been 1.1 to 1.8 million pounds of lobster landed between 1992 and 1997 (Table 4.7), valued at $4.6-6.7 million (Table 4.8), based on National Marine Fisheries Service (NMFS) data. Research programs conducted by UNH and Sea Sampling programs and dive surveys conducted by the NH Fish and Game Department and Normandeau Associates provide information on lobster populations, lobster habitat, and seasonal movements of

Frequency and volumes of dredging at harbors in New Hampshire: 1950-1993 (NAI, 1994). **TABLE 4.6**

Harbor	Number of Events (cy)	Aggregate Volume
Rockingham County		
Portsmouth Harbor and Piscataqua River		
Deep draft channels	28	1,708,006
Portsmouth Back Channel areas	3	900
Little Harbor	2	176,609
Rye Harbor	6	244,051
Hampton Harbor and tributaries	27	819,142
Strafford County		
Little Bay	1	556
Great Bay and minor tributaries	1	15,000

TABLE 4.7 *Recorded fish landings (landed pounds) in New Hampshire: 1992-1997.*

	1992	1993	1994	1995	1996	1997
Fish						
Alewife	9,802	2676				
Cod	3,076,564	2,525,274	2,576,567	2,362,707	2,384,561	1,712,106
Dogfish Spiny	402,184	1,641,614	2,597,792	2,106,255	1,079,522	1,009,140
American Eel	285	1384				
Winter Flounder	125,714	85,869	80,684	63,729	61,857	30,429
Hake Mix Red & White	23,231	8881	15,068	11294	30,295	36,629
Atlantic Herring	562,413	774,292	435,200	56,775	33,655	152,431
Pollock	1,028,452	1,082,602	886,582	745604	724,008	1,141,699
American Shad	9,903	6549	28,226	30561	35,561	25,436
Atlantic Silverside		8,888				
Smelt	36				346	
Tuna, Bluefin	146,042	102,881	110,654	83,716	85,203	
Shellfish and Worms						
Green Crab	3,515					
Rock Crab				24	118	
Lobster	1,529,292	1,693,347	1,650,751	1,834,794	1,632,829	1,166,068
Mussels						115
Sand Worms						599
Sea Scallop			442	256	256	1,065
Sea Urchins	102,494	46,163	12,117	4074	10,410	18,337
Shrimp (Pandalid)	220,733	972,705	1,148,571	1,658,588	1,692,017	1,225,021
Totals*						
Landed Pounds	9,471,438	10,474,945	12,155,643	11,723,114	10,123,219	9,398,882
Live Pounds	10,573,844	11,364,472	13,207,785	12,779,960	11,098,224	10,321,230

*Includes angler, bluefish, bonito, butterfish, crabs (Jonah, others) conchs, cunner, cusk, conger eel, flounder (Am. plaice, sand-dab, summer, witch, yellowtail), haddock, hagfish, silver hake, halibut, john dory, lumpfish, mackerel, menhaden, ocean pout, redfish, scup, sea raven, sharks, skates, squids, tautog, tilefish, yellowfin tuna, wolffishes.

lobsters. Banner and Hayes (1996) mapped potential lobster habitat in Great Bay in 1996 using a suitability index model, however, the lower estuary where lobsters are most abundant was not included in the study. Lobsters undergo a seasonal migration into the Great Bay Estuary in late spring and migrate well into Great Bay in the summer and early fall. Migrating lobsters only include lobsters at or near legal size, i.e., ≥40 mm carapice length. Many juvenile lobsters overwinter in the lower Piscataqua River and the near coastal area of New Hampshire. It is hypothesized that lobsters may take advantage of accelerated growth rates in the Great Bay Estuary in summer (Dr. W. Watson, UNH, personal communication). Though juvenile lobsters can be found in many habitats from the shallow subtidal zone and in the deepest channel areas of the estuaries, dive surveys and trap research indicate that their preferred habitat is rock-cobble bottom (Dr. Hunt Howell, UNH and Mr. Bruce Smith, NH Fish and Game, personal communication).

The NH Fish and Game Lobster Program study areas for both juvenile and adult lobsters include the Piscataqua River south of Dover Point, the lower river, outer Portsmouth Harbor and coastal area, and the Isles of Shoals. Sea sampling data indicates that catch per unit effort (CPUE) from 1992 to 1996 has been stable for all areas, with higher catch rates in the river and coastal area than at the Isles of Shoals (Figure 4.6). Dive surveys indicate that lobsters are most abundant from June through

Value ($) for recorded fish landings in New Hampshire: 1992-1997. **TABLE 4.8**

	1992	1993	1994	1995	1996	1997
Fish						
Alewife	4,900	576				
Cod	3,169,995	2,673,803	2,708,000	2,469,878	2,143,393	1,635,941
Dogfish Spiny	50,638	252,983	393,548	397,812	189,537	145,723
American Eel	430	2,076				
Winter Flounder	134,087	88,709	87,114	69,353	67,904	38,368
Hake Mix Red & White	6,469	1,972	3,366	2,541	6,250	7,242
Atlantic Herring	50,681	87,085	44,448	5,512	3,050	14,237
Pollock	743,414	837,745	803,698	725,822	578,714	780,992
American Shad	2,429	1,764	8,850	7,789	9,039	4,794
Atlantic Silverside		4,616				
Smelt	43				395	
Tuna, Bluefin	1,208,612	1,299,083	1,231,522	1,197,550	849,403	
Shellfish and Worms						
Green Crab	1,177					
Rock Crab				13	60	
Lobster	5,033,198	5,567,109	5,566,282	6,655,660	6,563,641	4,636,975
Mussels						12
Sand Worms						2,138
Sea Scallop			772	1,386	1,271	8,077
Sea Urchins	49,589	26,501	6,648	3,359	11,604	16,870
Shrimp (Pandalid)	252,492	932,247	818,524	1,420,581	1,274,983	1,047,257
Totals*						
Value ($)	12,054,527	12,941,155	13,397,832	14,925,401	13,531,968	10,500,781
Landed Pounds	9,471,438	10,474,945	12,155,643	11,723,114	10,123,219	9,398,882

*Includes Angler, Bluefish, Bonito, Butterfish, Conchs, Crabs (Jonah, Others) Cunner, Cusk, Conger Eel, Flounder (Am. Plaice, Sand-Dab, Summer, Witch, Yellowtail), Haddock, Hagfish, Silver Hake, Halibut, John Dory, Lumpfish, Mackerel, Menhaden, Ocean Pout, Redfish, Scup, Sea Raven, Sharks, Skates, Squids, Tautog, Tilefish, Yellowfin Tuna, Wolffishes

October. Lobsters were sampled using an otter trawl in the Portsmouth Harbor area in 1991 and the data indicate that juvenile lobsters are abundant (Johnston et al., 1994). The number captured per five minute tow at eight stations ranged from three to thirty three. Lobsters can also be plentiful in Great Bay at certain times of the year. Langan (1996) caught as many as 26 juvenile lobsters per 10 minute tow in the mid-Great Bay channel in July.

Lobsters and other marine organisms at sites outside Hampton Harbor have been monitored by NAI since 1975 as part of environmental assessments designed to determine the impacts of the Seabrook nuclear power station. The station became operational in August, 1990, and data can be categorized as pre-operational (1975-1989), operational (1991-present) and 1990 data during the transition. Nearfield sampling off Hampton Harbor (NAI, 1996) indicates that lobster abundance has been stable since 1982, however 1995 CPUE of all lobsters (legal and sublegal) was higher than all previous years. The high CPUE in 1995 could be related to elevated temperatures during 1995 (NAI, 1996). Changes in the legal size limit in 1984, 1989 and 1990 have resulted in a decrease in the capture of legal size lobsters and an increase in the number of juvenile lobsters caught (Figure 4.7).

In 1996, an oil spill in the Piscataqua River had a negative impact on lobsters, particularly those that were in traps at the time of the spill. An estimate of the number of lobsters killed from the oil spill is not available. A major rainstorm

FIGURE 4.6 *Comparison of sea sampled lobster catch per unit effort 1992-1996 (NHF&G Lobster Program).*

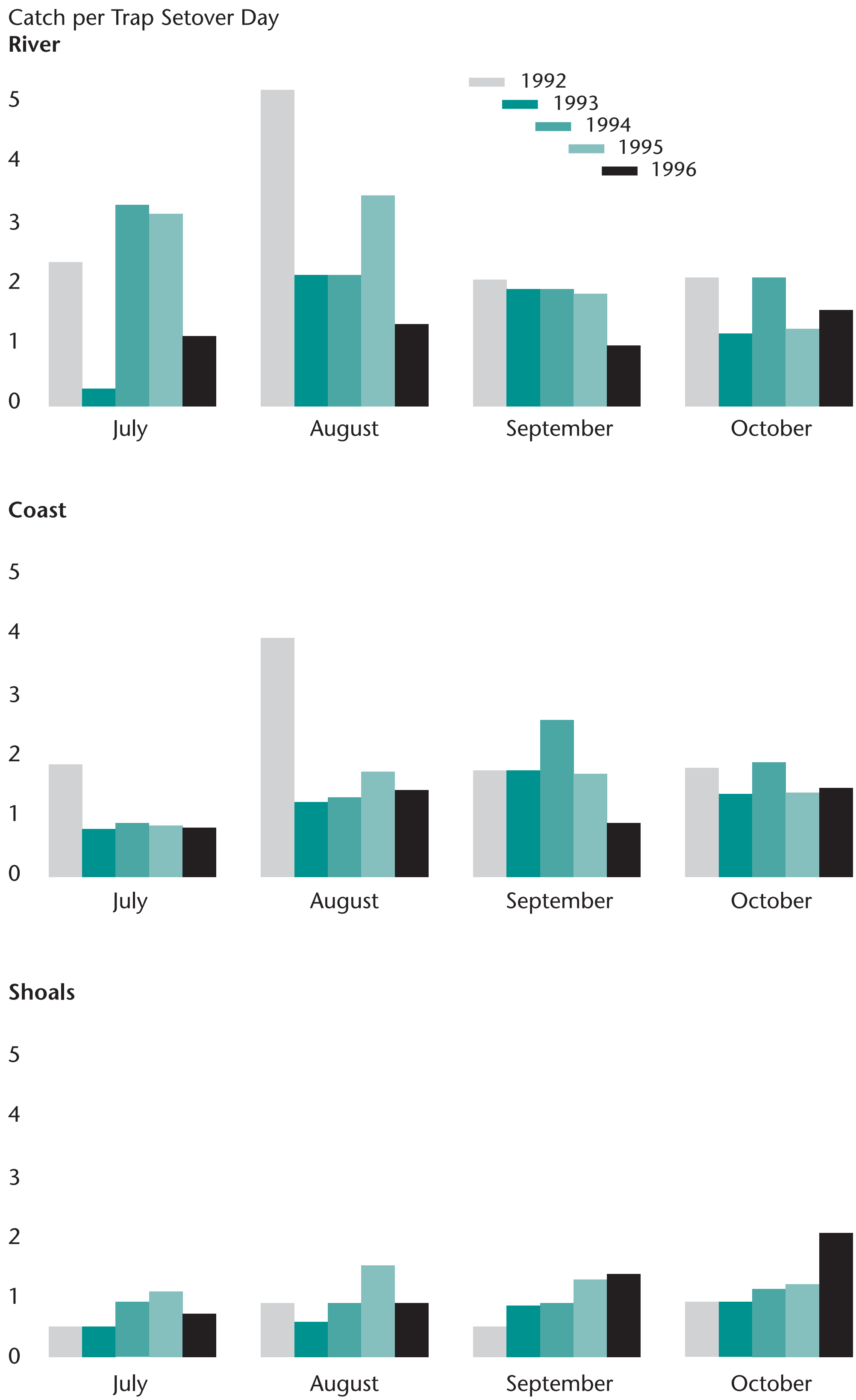
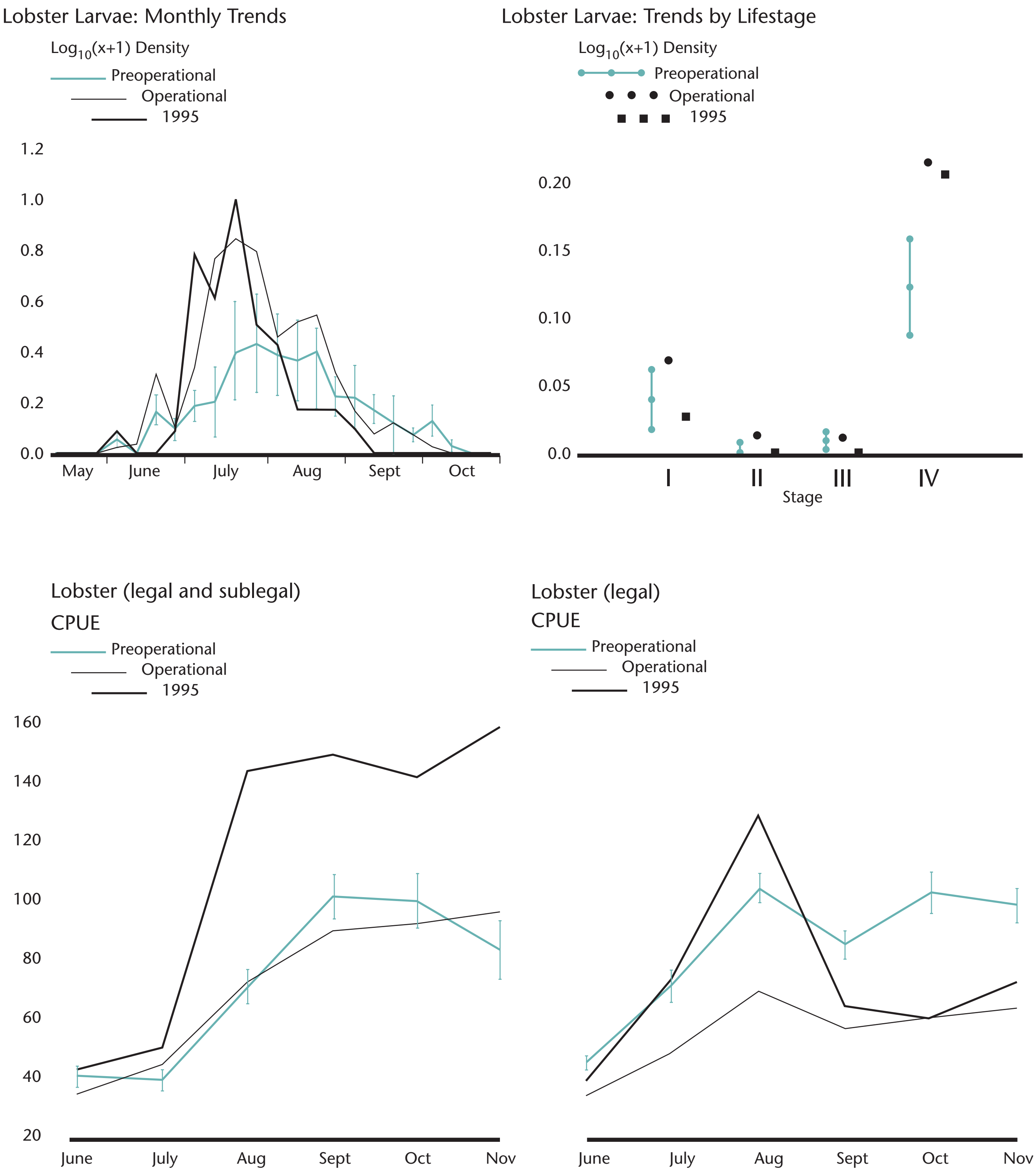


FIGURE 4.7

Preoperational (1975/78-1989), operational (1991-1995) and 1995 means of: a. Weekly density (no./1000 m2) of lobster larvae at Station P2, b. Lobster larvae density by life stage at P2, c. Monthly CPUE (15 traps) of total (legal and sublegal) lobsters at Station L1, and d. Monthly CPUE (15 traps) of legal-sized lobster at Station L1. Seabrook Operational Report, 1995. Vertical bars are 95% confidence limits.



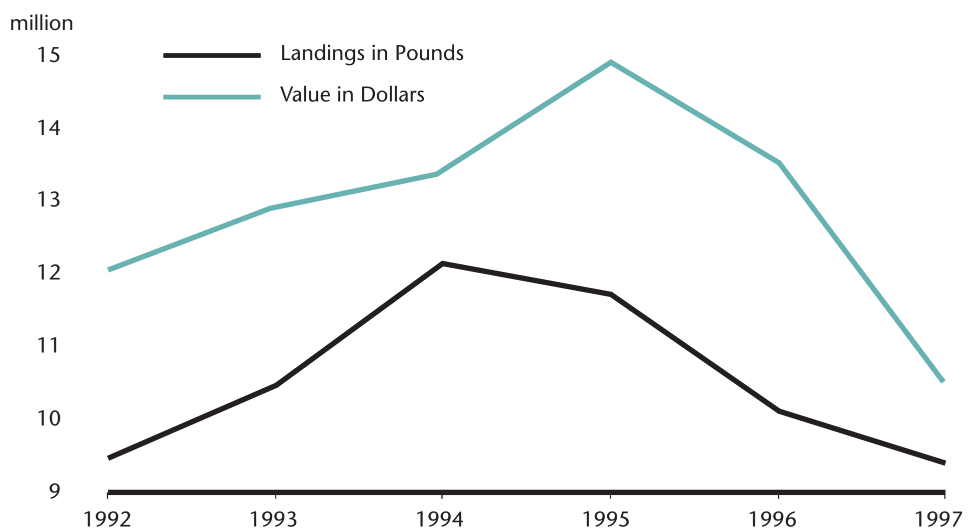
in October, 1996 dumped up to 12” of rain on the NH Seacoast on October 19 and 20. The sudden drop in salinity killed lobsters that were in traps as far down the estuary as Portsmouth. The total number of lobsters that succumbed to the massive freshwater input is not known, although this may in part explain the lower landed pounds and value for lobster in 1997 (Tables 4.7 and 4.8).

Other Commercial Fisheries

Other commercial fisheries in the Great Bay and Hampton/Seabrook estuaries include baitfishing for alewives, mummichogs (*Fundulus sp.*) and tomcod using gillnets, seines and minnow traps; trapping for eels, and angling and dipnetting for smelt. The landings and dollar value of these fisheries in the estuaries are not known, although limited data on the total catch of alewives, eels and smelt in New Hampshire are presented in Tables 4.7 and 4.8. There is also a commercial fishery for sea urchins, though this activity takes place primarily outside the estuaries in near coastal waters. Harvest methods include SCUBA and trawling with an urchin sled. Concern by some that the sled was disturbing bottom habitat prompted the NH Fish and Game to assess the impact caused by urchin dragging. Though the sled disrupted macroalgae, they found that the sled had little impact on nonvegetated hard bottom (Mr. Bruce Smith, NH F&G, personal communication). Thus, sleds can be used anywhere seaward of the Piscataqua River bridges and outside of the other New Hampshire harbors. The inshore/estuarine commercial scallop fishery was discussed in another section. It should be noted here that the inshore (>3 mi, < 25 mi) and offshore (>25 mi) groundfish populations have been in severe decline since the early 1980’s due to overexploitation (NOAA 1992). The reduced stocks and the strict regulations imposed on commercial fishermen has had a tremendous impact on coastal economies.

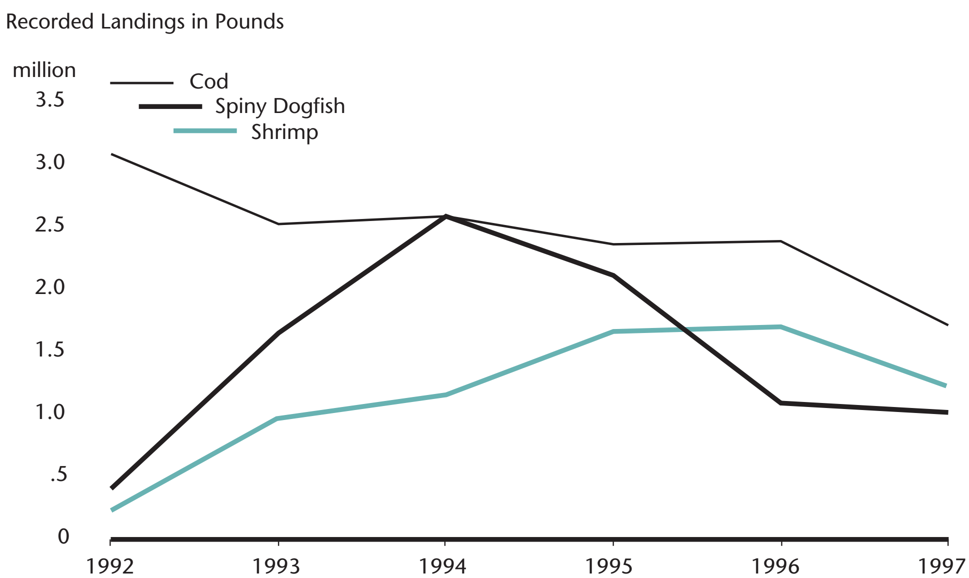
The commercial fishing fleet of New Hampshire also fishes in the Gulf of Maine outside the estuarine environment. The total recorded weight of fish landings caught by the New Hampshire commercial fishing fleet, and the value at the pier from 1992 to 1997 are summarized in Tables 4.7 and 4.8, respectively, based on NMFS data. The landed pounds have declined somewhat from highs of 12.1 million pounds in 1994, but are essentially the same as 1992 levels (Figure 4.8). The value of the fish declined to $10.5 million in 1997, the lowest recorded since 1992. Some of this may be attributed to the decrease in landings and value of lobsters in 1997.

FIGURE 4.8 *Total recorded fish landings and value in New Hampshire: 1992-1997 (NMFS).*

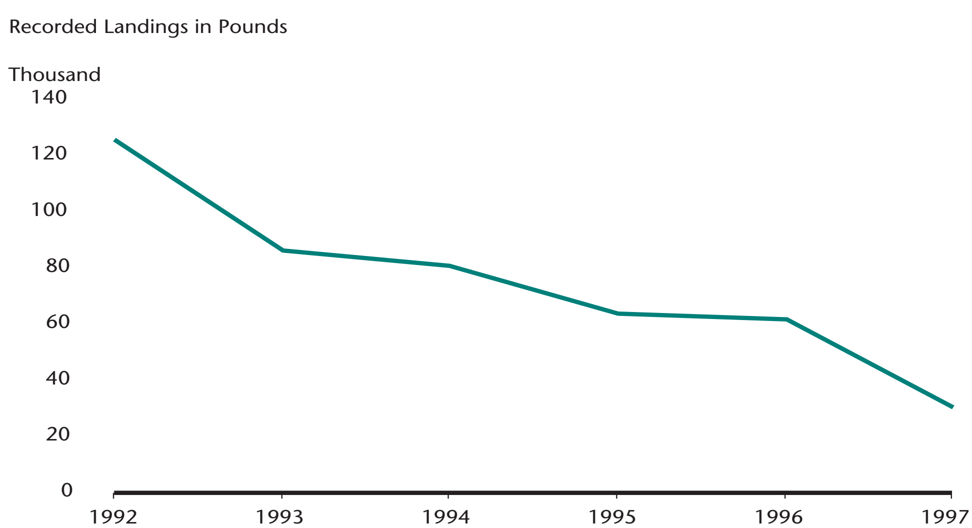


The landings and values of twenty finfish and shellfish species are listed in Tables 4.7 and 4.8. The most consistently important species are lobsters and cod, both in terms of value and landings. Whereas the landings of lobsters had been relatively constant until 1997, the cod landings have declined steadily since 1992, from 3.1 million to 1.7 million landed pounds (Figure 4.9). A similar trend is apparent for winter flounder (Figure 4.10). However, other species have exhibited different trends. The landings of spiny dogfish increased dramatically from 1992 to 1994, then declined sharply until leveling off after 1996 (Figure 4.9). Shrimp landings exhibited a steady increase from 1992 to 1996 (Figure 4.9). Sea urchin landings declined sharply from 102,494 pounds in 1992 to 4074 pounds in 1995, with a slow rebound since (Table 4.7). Other trends are also apparent, and these all reflect changes in world market prices, harvest pressure, government regulations and abundance of wild stocks. For example, the value of the lucrative tuna fishery was adversely affected in 1998 by the Asian financial crisis.

Recorded landings of cod, spiny dogfish and shrimp in New Hampshire: 1992-1997 (NMFS). **FIGURE 4.9**



Recorded landings of winter flounder in New Hampshire: 1992-1997 (NMFS). **FIGURE 4.10**



Aquaculture

Though aquaculture is one of the fastest growing industries in North America and globally, it has been slow to take hold in New Hampshire. In the early 1980's there were four commercial shellfish aquaculture operations in the Great Bay Estuary, engaged in the culture of indigenous (Eastern) oysters, the European flat oysters and hard clams (*Mercenaria mercenaria*). Three of these operations were located in New Hampshire and one in Maine, and only the Maine company is still in operation in 1998. Failure of the state shellfish sanitation program to meet the requirements of the National Shellfish Sanitation Program (NSSP) resulted in closure of all commercial marine aquaculture operations in New Hampshire by the U.S. Food and Drug Administration (USFDA) in 1989, and the three NH companies were forced to cease operations. To date, New Hampshire has been unsuccessful in gaining endorsement of its growing waters program (NSSP, 1995) from the USFDA, though the State's shellfish sanitation program has improved in recent years.

In 1996, a commercial oyster aquaculture permit was granted to three commercial fishermen participating in a research program associated with UNH. The project was funded by the NOAA/NMFS Fishing Industry Grants Program which was created to provide commercial fishermen with alternative business opportunities. The project produced nearly 730,000 oyster seed in 1996, which were planted at a five acre site near the mouth of the Oyster River in Little Bay. The project has continued to the present. The same program (NOAA/FIG) has funded a fisherman to research sea urchin culture, and commercial permits were granted to him in 1996, and to another individual in 1997. One of these operations was located in Hampton Harbor.

Other activity in shellfish culture includes a UNH sea scallop research project which is evaluating culture and stock enhancement techniques for scallops and several UNH sea urchin projects. In 1998, Spinney Creek Shellfish Co. in Eliot, ME, began operating a softshell clam hatching facility and successfully produced seed for outplanting experiments in flats on the Maine side of the Great Bay Estuary. UNH Cooperative Extension has also operated a culture facility for softshell clams in Seabrook. The facility is primarily used for 4H educational programs.

There has also been a great deal of activity in the past few years associated with finfish culture. A commercial summer flounder hatchery and nursery began operation in 1996. The company, Great Bay Aquafarms, is currently producing fingerlings for growout at other locations but plans to construct a growout facility on site in the near future. The company's operations are based in a warehouse on the PSNH power generation site in Newington, NH and are entirely indoors, using sophisticated recirculating and biofiltration technology to grow fish in land based tanks. It is the first commercial summer flounder operation in the U.S. More than 250,000 fish were produced in 1996. Research on lumpfish, several flounder species, cod and haddock is being conducted at the UNH Coastal Marine Laboratory. Engineering research on offshore fish pens has been conducted in association with one of the finfish projects by the UNH Ocean Engineering Department.

New Hampshire has the opportunity to develop a viable aquaculture industry. As far back as the 1940's Professor C. Floyd Jackson recommended developing aquaculture of clams and oysters in Great Bay (Jackson 1944). Ayer et al. (1970) determined that a seed oyster industry in Great Bay could be viable if hatchery reared seed were used. More recently, a NH legislative study committee on aquaculture (NH Legislative Committee, 1993) recommended development of an oyster culture industry. Research and development in other parts of the country and abroad have resulted in technologies that are suitable for New Hampshire. There are opportunities in the high technology, land-based finfish operations similar to Great Bay Aquafarms, as well as in environmentally friendly and ecologically beneficial shellfish culture. Mussels, scallops, oysters, clams and seaweeds are all excellent candidates for culture in New Hampshire and would provide economic as well as ecosystem benefits. Aquaculture could provide a means of maintaining seafood production in the New Hampshire Seacoast, and provide the beleaguered fishing industry with an alternative to harvest fisheries. A recent UNH Sea Grant Document (Howell et al., 1997) outlines the potential and benefits of aquaculture development in New Hampshire.

4.3.1.4 Marine Products

The NAI (1994) report identified three seafood processing facilities in New Hampshire. The Yankee Fisherman's Coop Pier in Hampton Harbor handles both shellfish and finfish, the Portsmouth Fish Co-op handles groundfish and Little Bay Fisheries in Portsmouth Harbor handles lobster.

4.3.1.5 Marine Plant Harvesting

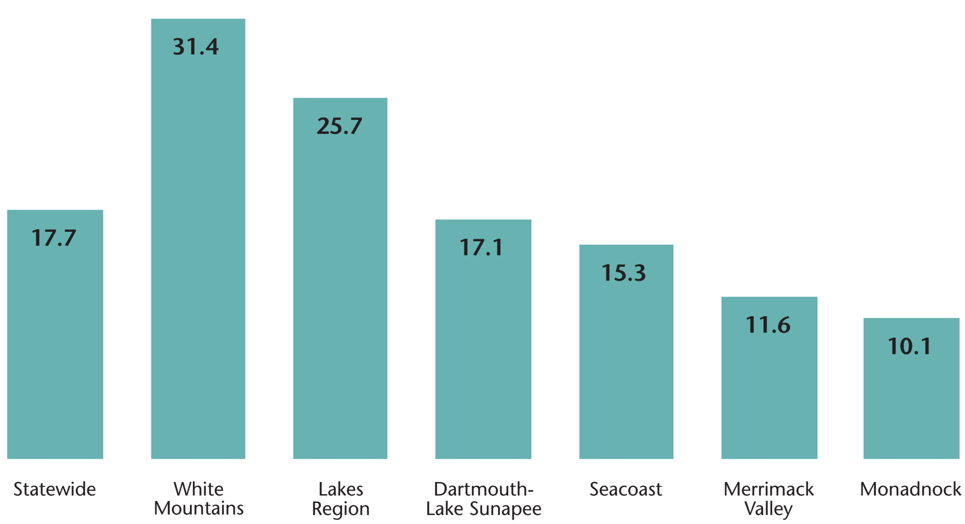
Salt hay farming continues to this day and has experienced a small revival in northern Massachusetts, yet the impacts from salt hay farming on salt marsh ecosystems are unknown (Rozsa, 1995). Algae have been harvested for various uses in New England, but such harvest in New Hampshire estuaries are poorly known and probably minimal. Impacts to the algal resources from experimental harvesting have been assessed for the red alga, Irish moss (Mathieson and Burns 1975). They found that plants could recover in a year after carefully controlled harvesting, but winter harvesting had greater impacts to the algal beds. Seagrass has been harvested in the northeast for building insulation and upholstery stuffing, but it is probably most widely used, as wrack collected from shorelines, for garden mulch and fertilizer. The scale of such activities in New Hampshire does not appear to have been large, and although their potential impacts are unknown, they are likely minor.

4.3.2 RECREATIONAL USES

4.3.2.1 Tourism Economics

Tourism and travel are important to the Seacoast economy (Okrant et al., 1994). Statewide in FY 1992, 10.3% (57,740) of all jobs were directly dependent on travel/tourism, and associated payrolls totaled $770 million, or 4.8% of all New Hampshire payrolls. In the Seacoast, 16% of the region's jobs were supported by tourism (Figure 4.11). Monthly spending for rooms and meals in the Seacoast during the six months from May-October

Percentage of jobs supported by travel and tourism in New Hampshire regions in 1992 (Okrant et al., 1994). **FIGURE 4.11**



was higher than during November-April, with a peak spending of >$20,000,000 in August.

There are numerous tourist-related activities in the Seacoast that involve use of charter boats. These activities include sport fishing, whale watching, windjammers/charter sailing, and harbor tours/day cruises. The numbers of vessels involved with these activities and their locations in the Seacoast are summarized in Table 4.5. None of the vessels are located in the tidal rivers, with a relatively even spread of locations for the different activities across the Seacoast.

4.3.2.2 Boating and Related Activities

The State of New Hampshire Department of Safety records boat registration and provides annual summaries. Boats are recorded by size, hull material and type (inboard, outboard, etc.). No differentiation by tidal and freshwater use is provided. A survey by NAI (1994) of harbor officials in New Hampshire showed 8,522 and 341 recreational vessels operated during 1992 in Rockingham and Strafford counties, respectively (Table 4.9). The NHDES used 1993 NH Department of Safety data to estimate that 3,468 vessels were tidal water registrations having marine sanitation devices.

Of the 8,863 total recreational vessels in 1992, 335 were at slips and 738 at moorings (Table 4.9). There were also nine marinas or yacht clubs in Rockingham County, plus four in Strafford County. In 1995, the NHDES counted nine marinas/yacht clubs. The New Hampshire Port Authority has authority over moorings. Permits are granted for moorings at 22 sites. Waiting lists are maintained for moorings at the different sites, with as many as 211 people waiting for Little Harbor moorings in December, 1996, and an estimated 20 years wait at Rye Harbor. Mooring holders are classified as resident and non-resident, as well

TABLE 4.9 *Private recreational vessels in coastal New Hampshire in 1992 (NAI, 1994).*

Site*	Total No.	Recreational Vessels at slips	Recreational Vessels at moorings
River			
Squamscott R.	80	15	4
Lamprey R.	45	30	14
Lamprey River Marina	30	30	0
Oyster R.	41	0	41
Cocheco R.	50	30	4
George's Marina	30	30	0
Harbor/Bay			
Great Bay	7	0	7
Little Bay	500	130	248
Great Bay Marina	158	100	58
Little Bay Marina	50	30	20
Portsmouth Harbor	7500	40	140
Portsmouth Yacht Club	25	20	5
Kittery Yacht Club	26	20	6
Portsmouth Back Channels	30	0	30
Little Harbor	330	160	120
Wentworth Marina	160	160	0
Hampton Harbor	280	50	130
Hampton River Marina	150	40	110
Total	8863	445	738
Rockingham County	8522		
Strafford County	341		

*Sites include 13 marinas, 9 in Rockingham County and 4 in Strafford County.

as mooring either pleasure or commercial boats. In 1991, there were 1390 mooring permits sold (Figure 4.12). The rapid increase from 1976 to 1991 leveled off after the NHPA adopted and implemented a harbor management plan in 1989. Mooring field parameters are set by the US Army Corps of Engineers, and current space for new mooring permits is extremely limited. In 1996, the areas with the most permits were Little Bay (222), Hampton (193), Little Harbor (131), Rye (129) and the Piscataqua River (119), with 268 permits spread around eight specific areas in Portsmouth Harbor, the Back Channel and other areas in Portsmouth. Very few new permits are expected in the near future.

Another means of assessing boating activity can be found in data from the New Hampshire Bridge Authority for openings at the Memorial Bridge in Portsmouth. The openings are a measure of traffic for vessels greater than 11 feet in height, and include sailboats, commercial tugs, barges, freighters and many pleasure craft. The monthly and annual counts for boats under the bridge from 1989 to present are shown in Figure 4.13. Recently there has been a slow, steady decrease in traffic, from 7470 in 1990 to 5860 in 1996. Figure 4.13 shows that the greatest traffic occurs during the summer months of July and August, whereas the lightest traffic occurs during winter months.

4.3.2.3 Recreational Fishing

The Great Bay Estuary supports a diverse community of resident, migrant, and anadromous fishes, many of which are pursued by recreational fishermen. Recreational fishermen mainly pursue striped bass, bluefish, salmon, eels, tomcod, shad, smelt, and flounder. Fishing is not limited to boat access, as cast or bait fishing is done from the shore in many places, from the bridges crossing the

Annual mooring permit sales by the New Hampshire Port Authority: 1976-1996. **FIGURE 4.12**

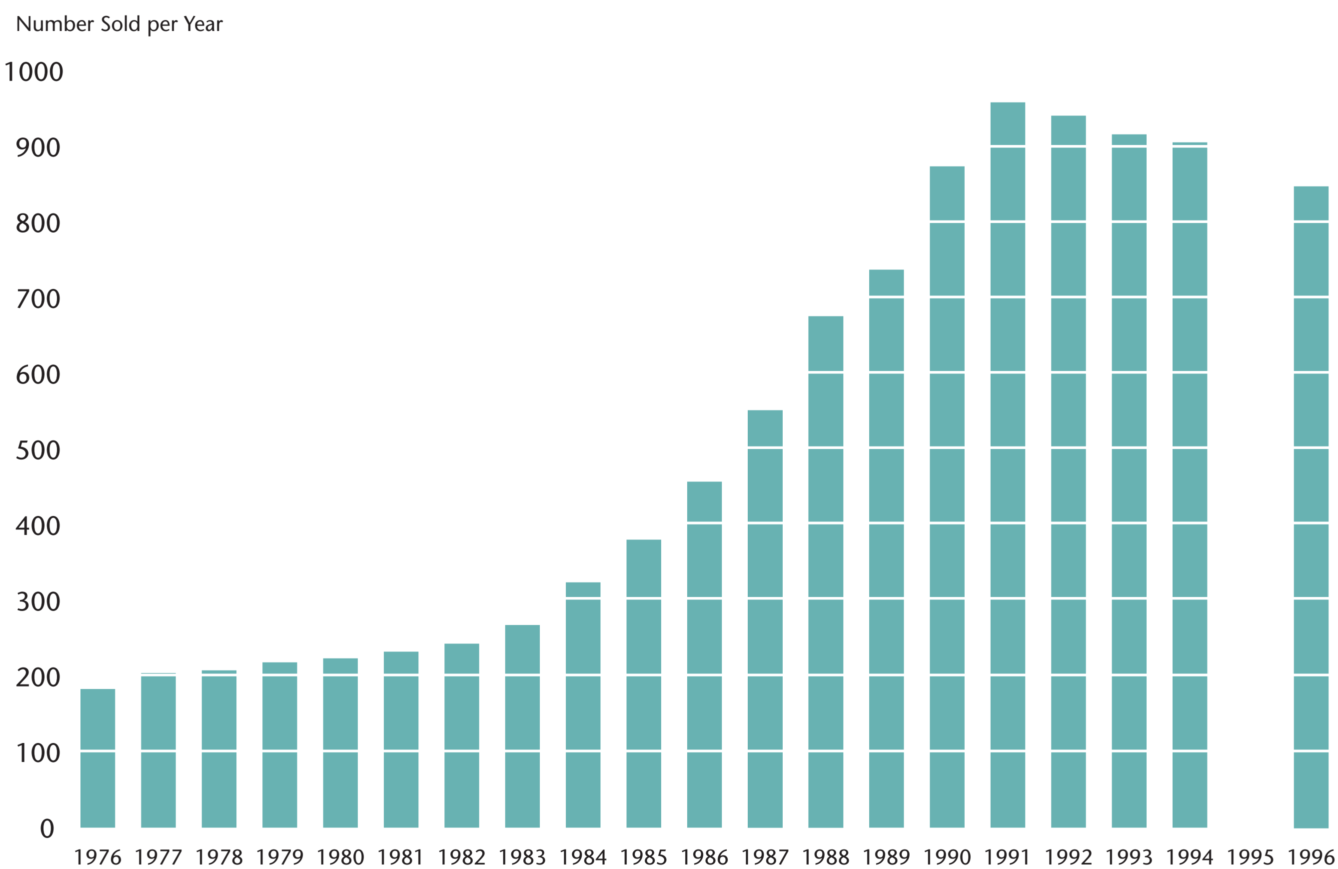
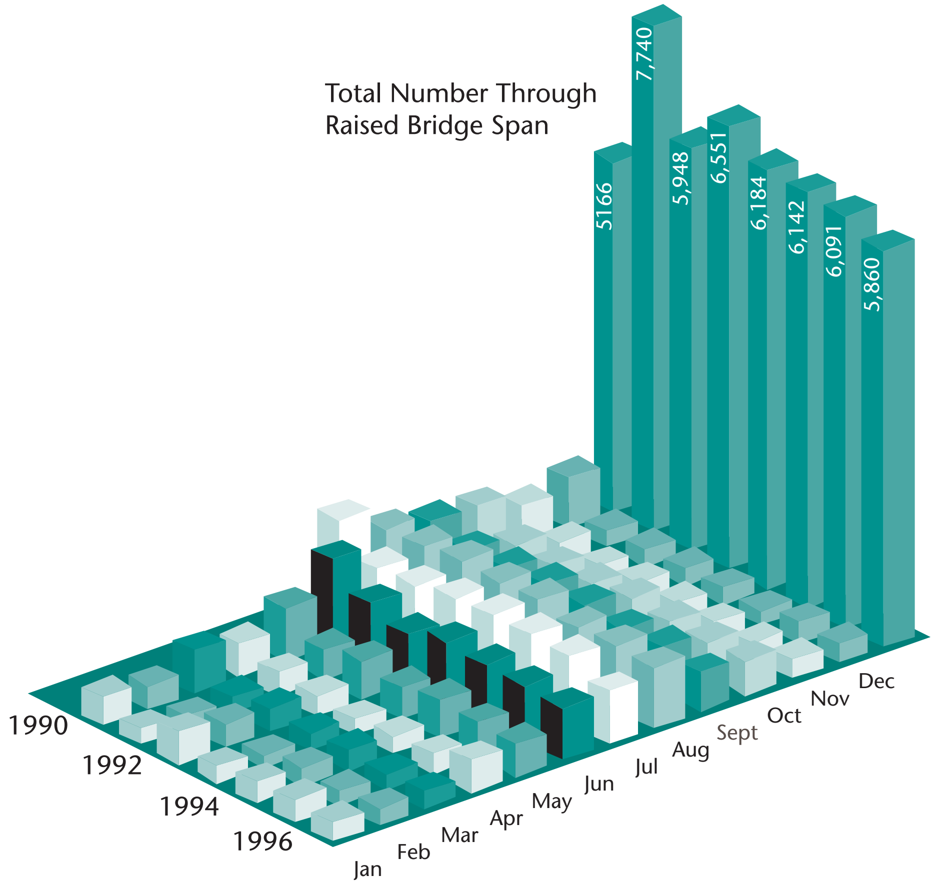


FIGURE 4.13 *Monthly and annual vessels passing under the raised span of the Memorial Bridge, Portsmouth, New Hampshire: 1989-1996.*



estuary, and ice fishing is popular in the tidal rivers. Recreational fishing in salt water does not require a license except for smelt in Great Bay Estuary; trout, shad and salmon in all state waters; and to take any fish species through the ice.

The yearly New Hampshire Recreational Saltwater Fishing Digest (NHF&G, 2000) provides profiles of the eight primary game fish species: striped bass, bluefish, Atlantic mackerel, rainbow smelt, winter flounder, Atlantic codfish, haddock and pollock, as well as profiles on twenty other game fish species that may be found in coastal New Hampshire. The digest also provides information on the ethics of recreational fishing, the 'Let's go Fishing' program, safe boating, a list and maps of coastal access sites, instructions on catch and release techniques, proper digging of clams and requirements for recreational lobstering.

Several charter boat companies in the Great Bay Estuary take fishermen to pursue striped bass, bluefish, and pollack, while companies operating out of Hampton Harbor carry fishing parties to inshore waters for clams and to the offshore waters to pursue cod, flounder, mackerel, and other fish. One of the major winter activities in Great and Little Bays is ice fishing for smelt. The smelt fishery in Great Bay occurs primarily in the Greenland Cove and the Lamprey, Squamscott and Oyster river areas from early January to March. Numerous businesses cater to smelt anglers, and access sites for smelt fishing are available. The NHF&G Department has pursued stocking and monitoring efforts on selected fish stocks (e.g., shad and Atlantic salmon; see section 4.4.3.1: Anadromous Fish Restoration) in order to enhance recreational fisheries (NHF&G, 1989). Another important recreational fishing activity is trap fishing for lobsters. Almost 150 recreational lobstermen set traps throughout the Great Bay and Hampton/Seabrook estuaries, with the Portsmouth Harbor area being a rather popular location.

Studies by NHF&G Department consultants identified substantial sums of monies spent on marine recreational fishing. An estimated 88,000 saltwater anglers spent over $52 million dollars in 1990 on fishing-related activities (approximately $600 per person). The largest expenditures were for food and beverages, automobile fuel, charter/party boat fees, bait and fishing tackle, and boat fuel. A substantial amount of that total is estimated to come from expenditures in Great Bay estuarine activities. More information on recreation fishing is presented in the Living Resources section (see Striped Bass, 3.2.1.1).

4.3.2.4 Shellfish Resource Management and Recreational Harvesting

Shellfishing is an important and popular recreational activity in the estuaries. The Great Bay Estuary supports a large recreational shellfishery for oysters, clams and mussels. Oysters are the predominant shellfish resource utilized in Great Bay, although Little Harbor supports more concentrated populations of clams. Major oyster beds are located in Great Bay proper, as well as in the Piscataqua, Bellamy, and Oyster rivers, with scattered pockets of oysters also found throughout the estuary (Figure 1.7). Though only recreational harvesting is allowed, the estimated dollar value of oysters in major beds was nearly $1.6 million in 1981 and $3 million in 1994. Approximately 5,000 bushels of oysters, valued at $300,000 are harvested annually by the 1,000 license holders (Manalo et al., 1991). Recreational harvesting of shellfish in the Great Bay Estuary is currently limited to most of Great Bay and Little Bay, with the Piscataqua River (including Little Harbor), and the smaller tidal rivers closed to harvesting due to bacterial pollution (Figure 1.8). The harvesting of softshell and razor clams in Great Bay, though difficult, became intensified in recent years because of limitations on harvesting of more popular clamming areas such as the flats in Hampton and Little harbors.

The principal shellfish resource in Hampton Harbor is the softshell clam, found in five major resource areas (Figure 1.9). These flats were closed in 1988, but with the conditional reopening of some of the flats in the fall of 1994 and further openings in 1998, almost 3,000 clamming licenses were sold in 1994 (up from 239 licenses in 1993). Prior to clam bed closures in 1988, the average number of licenses sold in the State between 1971-1987 was 6,400. Rye Harbor clam flats remain completely closed (Figure 1.11). The contribution of recreational shellfishing in Hampton Harbor to the local and state economy has been estimated to be $3 million per year (Manalo et al., 1992).

Effects of Classification on Shellfish Resource Productivity

Resource productivity of shellfish beds is determined by management of harvesting pressure and by the natural mortality, reproductive capacity and recruitment of the shellfish themselves. Causes of natural mortality include predation, disease, and siltation (in the case of oysters). Recruitment (addition of new individuals) depends on reproductive success, larval survival and successful metamorphosis. Classification of shellfish growing areas, which determines where shellfish can be harvested, plays an important role in shellfish resource productivity.

Oysters thrive in lower salinity waters than other important species of shellfish, and therefore are often found near sources of freshwater inflow such as tidal rivers. The locations of major oyster beds have been described in several publications dating back to the 1940's (Jackson 1947, Ayer et al 1970, Nelson 1981) and the current locations of beds are shown in Figure 1.7. Due to their proximity to pollution sources and associated higher than acceptable levels of fecal bacteria, all oyster beds in the Bellamy, Oyster, Piscataqua and Salmon Falls rivers, as well as those in southwest Great Bay have been closed since 1989, and some have never been open to direct harvest. In a turbid estuary like Great Bay, undisturbed (unharvested or uncultivated) oyster beds tend to accumulate silt which can result in burial in areas with low current velocities, and in impairment of larval attachment because of a lack of clean substrate even in beds with high flows. MacKenzie (1989) found that even a millimeter of silt on an oyster shell can deter larval settlement. The action of harvesting, whether by tongs or dredge, or cultivation with some sort of mechanical device, helps to remove silt, expose buried shell and provide a favorable substrate for larval settlement. A study conducted in 1991 (Sale et al. 1992) found that oyster beds at Nannie Island and Adams Point which are harvested recreationally with tongs and rakes, and beds on the Maine side of the Piscataqua River which are harvested with a small hand drag, showed major differences in population structure than beds in the Oyster River and on the New Hampshire side of the Piscataqua River which had been closed to harvest. The harvested beds showed higher relative densities of smaller oysters indicating better recruitment, while the populations in closed areas were skewed toward larger, older individuals. These findings are well supported in the literature (MacKenzie 1989, Visel 1988). Lack of harvesting and cultivation in some of the oyster beds in the Great Bay Estuary has probably contributed to significant loss of oyster areal coverage and density in the Oyster, Bellamy, and Piscataqua rivers and in southwest Great Bay (NHF&G, 1991).

Closure of the clam beds, and resulting absence of harvest pressure can have variable effects on clam populations. Besides the depletion of approximately 80% of adult clams, standard digging practices can reduce juvenile clam density by 50% through physical damage and exposure to predators (NAI, 1996). On the other hand, harvesting, which causes a change in sediment density and texture, can enhance settlement of larval *Mya*. Also, when tidal flat areas are undisturbed, blue mussels can form dense beds, sometime up to a foot thick, that can prevent settlement of clam larvae. In Hampton Harbor, closure of all flats in 1989 resulted in an overall increase in clam density, indicating that recreational clam digging was a significant source of mortality from adult and juvenile clams prior to April 1989 (NAI, 1996). The changes in clam density, however, varied from flat to flat. From 1990-1995, adult clam densities quadrupled in the middle ground, while Common Island densities did not change, and Hampton River density decreased by 50%. The effect of clam digging on the Common Island and Browns River flats, which reopened in 1994, was not apparent in 1995, as clam densities were similar in the two years. Though predation, disease and spatfall play a major role in determining clam densities in Hampton Harbor, a report by Savage and Dunlop (1983) clearly demonstrates the effect of clam digging on clam populations. Therefore closure of areas, whether for resource management or public health reasons, generally results in greater density of adult and juvenile clams.

Harvesting Effects on Other Wildlife

Though there is general agreement in shellfish producing states that oyster and some types of clam harvesting improve shellfish productivity (Visel 1988, MacKenzie 1989, Rask 1986) and do not harm benthic or pelagic species, there are few scientific studies that have dealt specifically with the effects of oyster harvesting on benthic populations. Dumbauld (1997) reviewed a number of studies of the impact of oyster culture and harvesting on benthic communities on the west coast of the U.S. and concluded that mechanical harvesting had no long term effects on benthic populations. Langan (1995) found no differences in density or species diversity of benthic invertebrates between an unharvested oyster bed in the Piscataqua River and one which was harvested with a towed hand drag.

There have been no documented adverse effects of scallop dredging on benthic populations, though Caddy (1973) reported damage to juvenile and adult scallops by a large, heavy offshore scallop dredge. It is unlikely that the smaller sized dredges used for inshore scalloping in New Hampshire cause the same magnitude of damage.

The effect of clam digging on undersized clams was discussed earlier, and there have been no documented studies of effects of clam harvesting on other wildlife in Hampton Harbor.

Siltation and Harvesting Effects

The effect of siltation on unharvested oyster bed productivity was addressed in an earlier section. It is reasonable to assume that mechanical or even hand harvesting of oysters will release sediment into the water column. No studies have been done in the Great Bay Estuary to assess the impact of resuspended sediments from oyster tonging, however, Langan (1995), measured suspended sediments in the track of a towed oyster drag on a Piscataqua River oyster bed. Water samples were taken with a submersible pump approximately 0.25 m from the bottom every 20 meters for a distance of 110 meters of the drag track. Ambient suspended sediment concentration was 10 mg/L. This concentration increased to 22 mg/L at a 10 m distance behind the drag and gradually decreased with distance before returning to ambient conditions at a distance of 110 meters. The study indicates that the disturbance of a towed drag is localized and suspended sediment conditions quickly return to ambient levels.

Though sediment disturbed by clam digging undoubtedly results in some resuspension of sediments when the tide begins to cover the clamflats, there has been no documentation in New Hampshire of adverse effects of resuspension from clam digging.

Management Strategies for Recreational Beds and Flats

Management strategies for recreational oyster beds consist of a daily harvest limit of one bushel of unshucked oysters per day per license holder, and a closed season in July and August. Oyster licenses may only be obtained by New Hampshire residents, and harvesting may only be done between sunrise and sunset by hand, rake or tong. The license must be displayed on the container and oysters may not be shucked on site. Areas open to harvest are determined by the NH Department of Health and Human Services and area closures are enforced by the NH Fish and Game Law Enforcement division. Oyster densities and sizes are monitored periodically by the Marine Fisheries Division of the New Hampshire Fish and Game. The recreational harvest is not recorded, therefore it is difficult to assess the effect of harvesting on oyster populations. Ayer (1970) estimated that annual harvest in the late 1960's to be approximately 3,000 bushels. An oyster survey by Manalo et al. (1991) estimated the harvest to be about 5,000 bushels based on responses from one third of license holders. A 1997 survey by NH Fish and Game estimates an annual harvest from 1993 to 1996 of approximately 3,000 bushels. Recreational license sales, which had been stable for may years at about 1000 licenses, declined to <800 licenses in 1996.

Recreational oyster management has also included an enhancement program undertaken by NH Fish and Game (Nelson 1989). Approximately 1000 bushels of surf clam shell were planted near Nannie Island and 500 bushels at Adams Point on firm bottom sparsely populated by oysters. Spatfall on the clean surf clam ($238/m^2$) was significantly higher than on existing shell ($8.2/m^2$). The project demonstrated that shell planting is an effective means of enhancing oyster populations. It should be noted that in high sediment areas, surf clam shells act similarly to sediment collectors as they almost always land cup up and fill with sediments, thereby reducing their effectiveness in catching oyster spat over time. Experiments with different types of shell as a spat attractant (Ayer 1970, Langan 1996) indicate that oyster shells and scallop shells are more effective.

Commercial harvest of clams in New Hampshire ceased in the 1950's. Regulations for management of softshelled clams have changed considerably over the years, with recreational harvesting becoming more restrictive in order to protect the resource. Clamming is permitted in daylight hours on Friday and Saturday from the day after Labor Day to May 31, with Hampton/Seabrook Harbor flats not opening until November 1. Clammers must have a valid license, available only to New Hampshire residents. Daily limit is a 10 quart pail of unshucked clams. The clam harvest has been estimated by head counts of clam diggers. During the period 1980-1982, at a time when there were 5,000 to 6,000 licenses, it was estimated that the annual harvest ranged from 2,000 to greater than 6,000 bushels (Savage and Dunlop 1983), though some documents report as many as 16,000 bushels harvested in the early 1970's. With the current rainfall condition (< 0.1 " of rain in the preceeding five days, except <0.25 " during December through March, or any occurrence of $\geq$0.1" rain in 24 h), the reduced season in Hampton Harbor, and fewer licenses sold since the 1989 closure, it can be surmised that current harvest is lower than the in previous 80-82 years. License sales peaked at nearly 14,000 in the 1975, dropped to less than 300 in the early 1990's and have rebounded in 1994-1996 due to the reopening of Hampton Harbor. During the 1996-97 clamming season (November 8, 1996 to May 30, 1997) in Hampton Harbor, clamflats were open for 19 days, during which an estimated 900 bushels of clams were harvested by an estimated 2,880 recreational harvesters (NHF&G, 1997b).

A clam enhancement study was undertaken by the New Hampshire Fish and Game in 1988 on the Willows clam flat in Hampton Harbor (Nelson 1989). Approximately 30,000 seed clams were planted at a density of 15 spat/m^2 under predator exclusion netting, and at 3.4 spat/m^2 in an adjacent area. Additional netting was placed on the flat to protect any natural spat that might settle. A little over two months after planting, the area was sampled and only two seed clams were recovered. It was determined that natural spatfall was very poor and that the planted clams either moved or were eaten by predators.

Illegal Harvesting

Illegal harvest of clams occurs in the Hampton/Seabrook Estuary. Over the past several years, there have been arrests to discourage illegal harvest. However, the activity, which is conducted under cover of darkness, is very lucrative and difficult to control, even though law enforcement is also concentrated on nighttime activity. Removal of large quantities of clams by illegal commercial digging presents a problem for resource management, and represents a public health threat if the clams are harvested from closed areas and sold to an unsuspecting public. Illegal harvesting of clams, oysters and other shellfish in other areas has not been documented.

Post-harvest Processing

The University of New Hampshire has a long history of scientific studies on post-harvest processing of shellfish to remove microbial pathogens. In addition, the existence of Spinney Creek Shellfish, Inc. (SCS), a commercial shellfish facility in Eliot, ME, has provided an excellent venue for scientific and applied studies on the post-harvest processing of shellfish. The potential for contamination problems in each step of their process has been evaluated (Howell et al., 1995). The effectiveness of ultraviolet depuration on oysters, clams and mussels has been confirmed at SCS and in laboratory-scale depuration tanks (Jones et al., 1991a&b; Panas et al., 1986). Although depuration is not effective for removing pathogenic vibrios from shellfish (Jones et al., 1991a&b), relaying shellfish into unfiltered estuarine water that does not contain pathogenic vibrios has been effective in reducing vibrio levels to low levels (Jones et al., 1995). Viruses are also generally resistent to removal via traditional depuration. Current research is underway at UNH/JEL to determine the potential for depuration of the human parasites *Cryptosporidium* and *Giardia* spp. (Dr. S. Torosian, personal communication).

4.4.1 BASE PROGRAM ANALYSIS

The following sections review the technical information that is available for various aspects of issues related to management of human uses of New Hampshire's Seacoast. Another NHEP document, the Base Programs Analysis (Carlson, 2000), reviews existing local, state and federal regulatory measures and natural resource management or education programs which impact estuarine resources. Thus, those topics are not included in this document.

4.4.2 LAND PROTECTION

The percentage (16%) of permanently protected land within 300 feet of the shoreline of New Hampshire's tidal waters (Figure 4.4) is significant in that a much lower percentage of shoreland is available for development than in inland areas. Much work to prioritize land areas, based on evaluation of habitat value, has been completed.

Various strategies have been used to help identify and prioritize important habitat areas in coastal New Hampshire. Important habitats in coastal New Hampshire have been identified using a GIS (Sprankle, 1996). All habitat was ranked based on the habitat requirements of 55 species of concern. Ranks were summed for all species and habitats potentially important for the target species were mapped. In a related effort, New Hampshire's most important natural resources were identified (Ueland et al., 1995). The Seacoast and Great Bay were identified as high priority areas, based on the value of their natural resources. The GIS maps include a delineation of important natural resources and habitats. Banner and Hayes (1996) conducted a pilot study in coastal New Hampshire to develop methods for selection of evaluation species, assessing habitat suitability and mapping habitat, as well as to identify and facilitate protection of important habitats using that information. They mapped the habitats for 25 species that were selected based on local concerns and a species priority list for the Gulf of Maine.

GIS Surveying in process

4.4.3 HABITAT RESTORATION AND MITIGATION

Human development and pollution of estuaries and coastal areas has led to the destruction of important habitats throughout the world. Though New Hampshire's estuaries are in good condition relative to many other estuaries on the east coast of the U.S., human activities that occurred prior to the realization that natural habitats play an important role in the ecology and economy of the region have resulted in impacts to important estuarine habitats. Many tidal marshes have been filled and tidal flow restrictions caused by road construction has degraded others. Dams constructed on tidal rivers prevent passage of anadromous fish. Sediment erosion from clearcutting, and sawdust from lumber mills has smothered some shellfish beds, while historical direct dumping and discharge of untreated industrial and municipal waste has contaminated others. Though the regulatory framework for protecting further habitat destruction has been established, restoration of habitats that were destroyed or adversely impacted by past activities has been and will continue to be a priority in New Hampshire's estuarine and coastal areas. Over the past two to three decades, the development of techniques for habitat restoration has made the prospect of restoring or creating habitats a viable option for coastal resource management.

A mitigation process is required in federal regulations for major development projects that impact legally protected environments (e.g., wetlands). The regulation requires three steps: investigation of alternative sites, reduction of the proposed impacts, and compensatory action to replace the functions and values of the habitats to be impacted by the development. When estuarine or coastal habitats are involved in such a development, habitat restoration is the preferred mechanism of compensatory mitigation.

4.4.3.1 Anadromous Fish Restoration

During the industrial development period in the 18th and 19th centuries, dams were constructed on nearly all of New Hampshire's tidal rivers. The dams prevented access by anadromous fish to their freshwater spawning grounds. Beginning in the 1970's, fishways or fish ladders were constructed on the Cocheco, Lamprey, Oyster, Taylor, Winnicut and Exeter rivers (Figure 4.14). The fishways now allow passage of river herring, shad, lampreys and many other species from tidal to fresh waters to spawn.

Currently, the NH Fish and Game Department is maintaining fishways and monitoring the spawning runs of several species. They are also working to restore anadromous fish populations through their Coastal Anadromous Fish Species Program. The goals of this program include raising sea-run salmon for stocking coastal rivers; the transfer of spawning shad into coastal rivers; and construction of fish passage systems. Approximately 250,000 salmon fry were stocked into the Lamprey and Cocheco rivers with the help of 50-100 volunteers in 1996 and 1997 (Cornelisen, 1998), a practice that has occurred yearly since the 1980s. Ongoing NHF&G monitoring is tracking the progress of these efforts and provides valuable data on numbers, size, sex and age of returning fish populations.

4.4.3.2 Shellfish Restoration

Restoration of degraded or depleted shellfish beds has become a major focus in the United States and abroad. There is not only an economic incentive, but an ecological one as well. Areas that have lost the majority of their shellfish resources (Chesapeake Bay, Delaware Bay) are experiencing severe water quality problems due to a large extent to the loss of filter feeders. Oysters in the Chesapeake Bay in 1900 were capable of filtering the entire water volume of the bay in 24 hours. The reduced number of oysters (due to disease and overharvesting) would now take nearly a year to filter the same volume.

The application of techniques developed by the aquaculture industry has made restoration of natural oyster beds

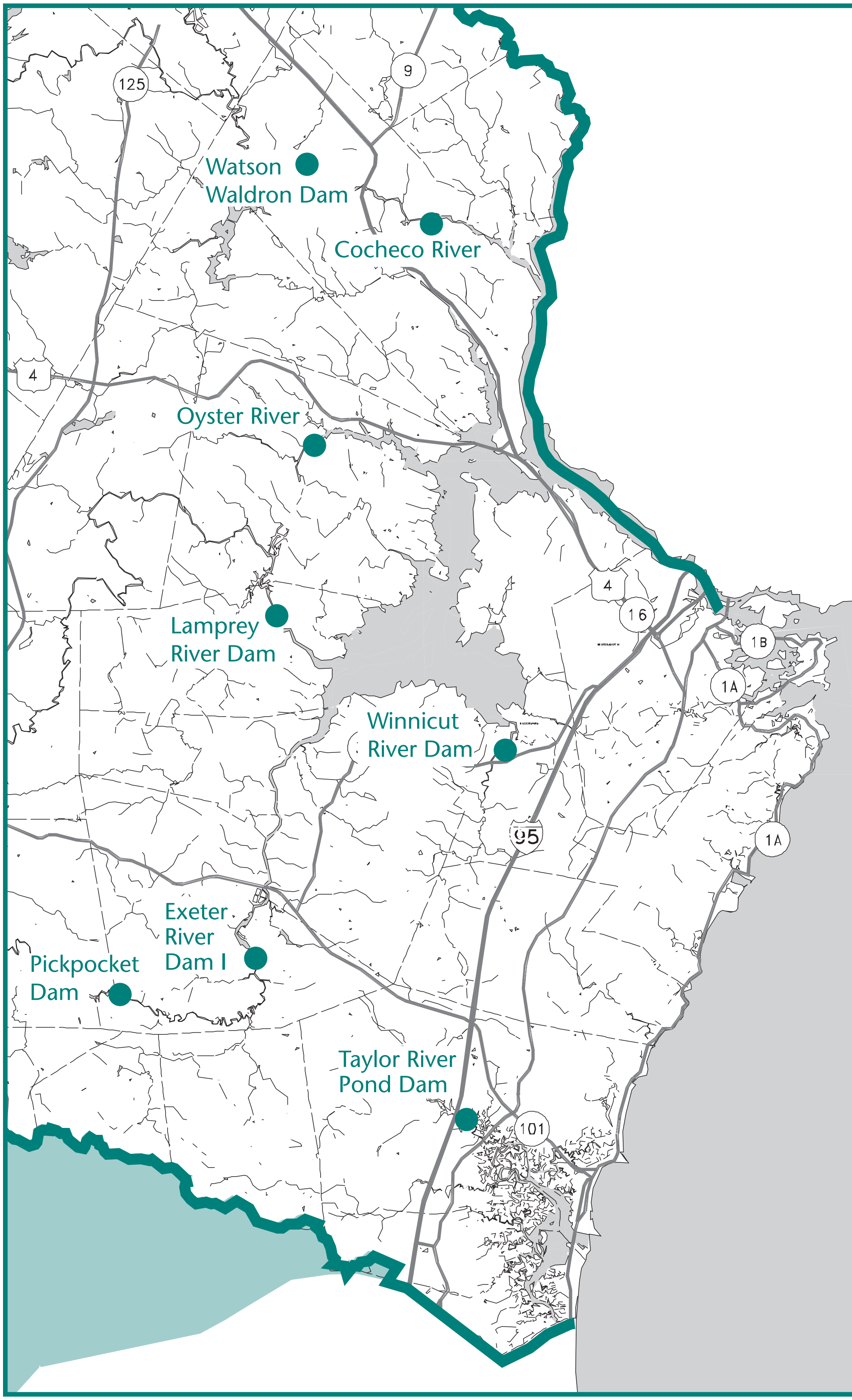


FIGURE 4.14

Fish ladders in the New Hampshire Coastal region.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possible. Shell planting (described in section 4.2.1.4), remote setting using hatchery reared larvae and construction of artificial and shell reefs have all proven successful in oyster restoration. In areas where oyster diseases are present, resistant strains of oysters may be introduced. An aquaculture project by researchers at UNH/JEL which began in 1996 to determine whether oyster aquaculture is a feasible alternative for commercial finfish harvesters has employed remote setting of hatchery reared larvae on natural and artificial cultch. Good results were obtained using French spat collectors called "Chinese hats", and 130,000 spat were produced on 30 Chinese hat units and planted in the fall of 1996. An additional 600,000 spat set on shell were also planted. Growth and mortality of the oyster seed is being monitored, and a second year of setting commenced in May, 1997. These same techniques can be used to restore public recreational beds. In addition, oysters in suspended culture can be used to filter phytoplankton from waters such as the Salmon Falls River where intense blooms occur in summer. A current UNH project has established two new oyster beds in the Salmon Falls River and will determine beneficial impacts on water quality.

Softshelled clam restoration is not quite as advanced as oyster restoration. A past restoration effort was described in section 4.2.1.4. A number of techniques ranging from planting hatchery reared clams to manipulating the flats to enhance natural settlement have met with mixed success. There are several techniques that have been used in Maine and Cape Cod that have shown excellent results (Beal 1994; Leavitt, personal communication; Gowell, personal communication).

Though the amount of estuarine habitat suitable for sea scallops is small, sea scallops are an important winter fishery for some NH lobstermen and an active recreational fishery for SCUBA divers. Sea scallop beds are located at the mouth of Portsmouth Harbor from Salamander Point to Fort Point near Fort McClarey, in Spruce Creek and from Fort Point to Jaffrey Point along the New Castle shore. Density, size (age) distribution and movement of scallops was studies by Langan (1994) in the lower Piscataqua River. In 1996, artificial spat collectors were deployed in the river to test the feasibility of spat culture and natural enhancement using non-destructive methods to collect natural scallop spat. Similar techniques are practiced in Canada, New Zealand and Japan. These methods form the basis of sustainable commercial scallop fisheries in those countries, and have been shown to enhance natural populations by increasing recruitment in the vicinity of the collectors. Spat settlement in the area under the collectors were monitored in June, 1997, and compared to adjacent areas to determine the effectiveness of the collectors for enhancing natural populations.

4.4.3.3 Saltmarsh Restoration

Restoration of many salt marshes in New Hampshire has focused on reestablishment of tidal exchange to marshes where tides have been restricted by undersized and damaged culverts (Drakeside Road Marsh, Locke Road Marsh), water control structures such as flap gates (Mill Brook Marsh Stuart Farm), and berms of debris or dredge spoil (Awcomin Marsh in Rye Harbor, Sandy Point Marsh at Great Bay NERR) (Morgan et al., 1996). Reestablishment of tidal regimes similar to those found downstream of the restriction has resulted in rapid recovery of several functions and successful restoration projects (Burdick et al., 1997). Restoration activities at 6 restrictions has improved tidal flooding to approximately 60 acres of impacted salt marshes in New Hampshire by 1997. Other areas present unique problems. For example, a small salt marsh (<1 acre) was created on New Castle Island at the southern entrance to Little Harbor as mitigation for the Wentworth Marina. The marsh failed but was replanted by a new contractor following regrading and deployment of wave barriers to reduce wave exposure. The marsh was replanted in stages (from 1988 to 1992) and is gradually developing (Dr. D. Burdick, UNH, unpublished data).

Information on nineteen recent salt marsh restoration projects is presented in Table 4.10. These data have been compiled as part of a Gulf of Maine-wide project (Cornelisen, 1998). The cited projects were supported by many different agencies for a range of different purposes. The total estimated acreage of saltmarshes that have been targeted is 433 acres, and the cost per acre ranged from $800 to $236,000. The high per acre cost of some of the compensatory projects may be because of the requirement of the permit applicant to replace habitat

Recent saltmarsh restoration projects in New Hampshire (Cornelison, 1998). **TABLE 4.10**

Project Title	Funding Agency	Town	Area (acres)	Cost/acre	Project Type*
Sandy Point salt marsh	NHOSP/CP	Stratham/Greenland	5.0		r
Little River salt marsh		North Hampton	156.0		r
Bass Beach salt marsh		North Hampton	10.0		r
Awcomin salt marsh	NHOSP/CP; USACE;USFWS	Rye	35.0	$3,167	r
Locke Road	NH OSP/CP	Rye	53.0	1,806	r
Haul Road salt marsh		Seabrook	0.5		c, r
Wentworth Marina		New Castle	1.0		c, cr
Mill Brook salt marsh restoration		Stratham	10.0		r
N.H. marine terminal mitigation	NHPA	Portsmouth	1.6	236,220	r, cr
Seabrook wastewater treatment facility		Seabrook	0.6		c, r
Rye Harbor		Rye	15.0		r
Route 101: Squamscott River bridge	NHDOT	Stratham	3.7	81,071	c, r
Winnicut River salt marsh		Greenland	?		r
Fairhill saltmarsh restoration project		Rye	12.2		r
Landing Road salt marsh		Hampton	?		r
Stuart Farm	NHOSP/CP	Stratham	4.0	5,536	
Route 1-A	NHOSP/CP	Rye	40.0	1,229	
Drakeside Road	NHOSP/CP	Hampton	22.0	1,392	
Marsh Road	NHOSP/CP	Rye	50.0	800	
Total			**419.6**		

* c= compensatory; r= restoration; cr= creation.

Salt marsh restoration at Fairhill Marsh.

GBNERR

function, often in close proximity to the site of habitat loss (Cornelisen, 1998). High costs are a function of the removal of fill, planting, land acquisition and other expensive requirements. There is a stark contrast in cost between low-cost habitat restoration projects, which are not only lower cost projects but also can result in much more acreage restored, and habitat creation projects.

4.4.3.4 Eelgrass Restoration

In addition to the mitigation activities described below, eelgrass restoration efforts have been conducted on an experimental scale at several sites in the Great Bay Estuary (Carlson, 1997) and several more recent eelgrass restoration projects have been funded by the USEPA. One project is located in the Bellamy River and another is in Little Bay, where eelgrass beds, possibly killed by the "wasting disease", have not become reestablished for over 10 years.

In Rye Harbor, another US EPA-funded eelgrass restoration is designed to create eelgrass habitat and potentially benefit the ecological health of the harbor. The eelgrass distribution in Rye Harbor has been limited to a series of small beds in a perched intertidal tide pool. Reconfiguration of the storm-distributed rock and sediment material across a broad area in the inner harbor will allow the expansion of the tidepool eelgrass habitat. To encourage this expansion, some transplanting will be done.

4.4.3.5 Port of New Hampshire Mitigation

When the N.H. Port Authority decided to expand the State Port Facility by adding a new pier, containment structure, wharf, and two-lane connecting bridge, it was clear that some estuarine habitat would be destroyed or affected in the process. The U.S. Army Corps of Engineers and the N.H. Wetlands Board issued a permit for the $18 million construction, with State and Federal resource protection agencies stipulating that the permit include provisions for mitigation of the projected habitat loss (Short and Short, 1997). Additionally, as an unusual provision, the mitigation was required to meet specific success criteria before actual port construction could begin. The NHPA Mitigation Project cost $1.8 million. It is a large and successful compensation for environmental impacts to the estuary with sites located along the Piscataqua River and in Little Bay.

The multi-year mitigation project combined the efforts of the University of New Hampshire, the private consulting firm of Dames and Moore, and a salt marsh restoration company based in Massachusetts called Great Meadow Farms. Eelgrass, salt marsh, and mud flat habitats were created during the three-year effort. The three-habitat mitigation was meshed where possible, so that the habitats could develop in proximity, as they often do in nature. Finding sites for the various mitigation was a major preliminary task. The mitigation work is now complete and has entered a 15-year monitoring phase; this long-term monitoring is another unique aspect of the project.

More of each habitat was created or enhanced than was projected to be lost to construction of the new port facility. For eelgrass, the created:impacted ratio was 1.4:1; for salt marsh the ratio was 2:1; and for mud flats the ratio was 1:1. In part, these ratios were designed to compensate for the gap in overall habitat values to the estuary as the newly created habitats established themselves. Transplanted salt marsh is particularly slow to redevelop all of its functions and values, and therefore had the highest ratio.

Mitigation success criteria were based largely upon "best estimate" and were without strong scientific foundation. The mitigation project was held to success criteria that included plant survival and plant coverage. A NOAA-funded research project based in part on the port mitigation determined what kinds of criteria are most effective in judging mitigation success.

A total of 6.5 acres of eelgrass was transplanted into the estuary, making this the largest eelgrass transplanting project ever done on the east coast. Several locations were chosen along the Piscataqua River and in Little Bay, i.e., in quieter areas of these heavily travelled waters. Transplants put into intertidal sites largely failed, as eelgrass was scraped away during the following severe winter by large sheets of tidally-driven ice. Subtidal sites were largely successful and have filled in to create new eelgrass habitat. The mitigation efforts have resulted in the development of new, more effective methods for transplanting eelgrass (Davis and Short, 1997).

A unique aspect of the Port mitigation project was its replacement not only of eelgrass habitat, but of potential habitat as well. The Port construction was due to impact areas where no eelgrass grew, but that were very suitable for eelgrass growth and that likely sustained eelgrass habitat in the past. Therefore, compensating for the loss of such potential habitat was considered by the regulatory agencies as they formulated the permit for Port construction.

Creating new mudflat areas required finding previously-filled upland areas that could be excavated and put back under water. Over 5 acres of mudflats were enhanced by increasing tidal flooding to a cove. A dam was removed and the channel deepened, so that a previously rarely flooded area that often smelled bad is now flushed by tidal waters twice daily. New mudflats were also created (1.4 acres) by excavating previously filled upland, resurfacing it with mudflat sediment, and grading it to intertidal elevations (Grizzle, 1997).

Kelp beds were created along the boulder borders of the Port mitigation terrace on the Piscataqua River. Propagules set on the boulders and grew rapidly over the two years since the terrace was installed, creating a new kelp forest habitat.

Salt marsh was transplanted into two sites near the proposed Port expansion project (Burdick, 1997). The salt marsh sites were both chosen as being heavily degraded estuarine shoreline in need of enhancement and reconstruction. At each site, degraded estuarine shoreline was reconfigured to conform to the tidal regimes required by salt marsh plants, which are very sensitive to submersion times and frequency. A total of 1.6 acres of salt marsh was transplanted (Table 4.10), transforming a debris-strewn stretch of shoreline near an old railway bed and a much-altered roadway and bridge abutment back into productive estuarine habitat.

4.5

SUMMARY OF FINDINGS

The review of technical information on human uses and resource management in coastal New Hampshire showed varying amounts of information are available for the different areas of concern. The important observations on trends and information gaps are presented below.

- The population and density of the two coastal counties in New Hampshire have exhibited steady increases over the past twenty years, and this trend is projected to continue at a somewhat slower pace. The continuation of increases in population and density in New Hampshire's two coastal counties is a concern because of the accompanying increases in development, use of coastal resources and production of pollutants, and the potential adverse impacts these factors can have on environmental quality.
- Commercial fishing is the coastal industry with the most significant economic activity and employment. This industry is subject to destabilizing influences such as world market prices, harvest pressure, government regulations, weather and abundance of wild stocks.
- Commercial lobstering has been the highest value fishery in New Hampshire. Landings have been relatively stable over the past decade, although extreme weather events have had adverse effects on the harvest in estuaries.
- There are some coastal communities that have high percentages of developed land and little more area available for development. In addition, much (40%) of the remaining developable land within 300 feet of tidal waters is permanently protected.
- There is a wide variety of important vessel-related activities, including commercial fishing, shipping and recreational boating, the latter two of which may exhibit further increases in activity.
- Dredging activities are well coordinated and regulated and will continue to be important for maintenance of safe and accessible harbors.
- Aquaculture is beginning to become established in New Hampshire. The successful four-year operation of a land-based summer flounder facility is complemented by research and pilot projects on other finfish, shellfish and a variety of types of aquaculture operations.
- Recreational activities such as boating, fishing, shellfishing and tourism are growing in importance as economic activities in coastal New Hampshire.
- Recreational shellfishing is currently limited by water quality. Improvements in water quality and management of shellfish resources that are anticipated as part of a bolstering of the State's shellfish program will benefit all forms of recreational and commercial uses and the environmental quality of coastal New Hampshire.
- Numerous recent and on-going studies have provided information to help planners of future development to identify and prioritize ecologically important habitats for potential protection and conservation.
- Improvements in environmental quality and ecosystem integrity have been realized through efforts to restore habitats and species such as saltmarshes, eelgrass and anadromous fish. Other important habitats like shellfish beds are currently the subjects of research and will greatly benefit and provide enhanced estuarine-wide environmental quality from future significant restoration efforts.